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"THE INVESTIGATION OF FLAME SPREADING OVER THE SURFACE OF IGNITING SOLID PROPELLANTS"

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INTRODUCTION

An experimental study of the phenomenon of flame spreading over the surface of igniting solid propellants is being conducted on a fundamental level. The flame spreading velocity is being measured as a function of several variables of both theoretical and practical importance. By measuring the variation of the flame spreading rate as a function of these variables, it should be possible to reveal the underlying mechanism and form a rational basis for the design of solid propellant rocket motor ignition systems, at least as far as the flame spreading phase is concerned. Eventually, actual composite propellants will be studied, but as the physical separation of constituents gives rise to an extremely difficult-to-describe, vaporization and gas phase mixing (preceding ignition and flame spreading) simpler systems are being studied initially in order to circumvent this difficulty.

REPORT OF PROGRESS DURING THE SUBJECT PERIOD

During the subject period, the flame spreading velocity over the surface of a broad range of propellant constituents has been measured as a function of several experimental parameters; pressure level, reactive gas concentration in the surrounding atmosphere, and surface condition of the solid. In addition to the previously studied double base propellants (Ref.1), the flame spreading velocity over the surface of various fuel-binder materials (polystyrene and polymethylmethacrylate) in oxidizing atmospheres, and that of an oxidizer material (ammonium perchlorate) in fuel atmosphere, is being measured by means of the well-developed experimental techniques of Ref 1. Briefly, small test specimens (1-1/2" x 3/8") are mounted horizontally in relatively large, vacuum-tight, test chamber. After charging the chamber with a selected test gas, the sample is ignited along a top edge by means of an electrically heated wire, and the flame spreading velocity over the surface is measured by cinematographical analysis.

The flame spreading velocity over polystyrene and polymethylmethacrylate surface in 100% oxygen has been measured at different pressure levels for four different surface conditions: (1) smooth homogeneous solid, (2) loose beads of various sizes, (3) pressed beads, and (4) chemically bonded beads. It has been found that the flame spreading velocity is a function of surface roughness at all pressure levels tested. For example, the highest spreading velocity is obtained over a loosely packed bead surface while the smooth homogeneous solid exhibits the lowest velocity. Further, the pressure exponent of the flame spreading velocity increases with surface roughness. This surface roughness effect is exhibited by polymethylmethacrylate as well as polystyrene.

The flame spreading velocity over the surface of ammonium perchlorate, the most common composite solid propellant oxidant, in a 100% methane atmosphere has been measured at different pressure levels for various surface roughnesses. The loose beads of ammonium perchlorate were hydraulically pressed at varying pressures (8000 - 1,6000 psi) to produce a variety of surface roughnesses. Although the absolute magnitude of the flame spreading velocity over the ammonium perchlorate is less than 1/3 of that exhibited by the fuel-binder materials, the characteristic dependence on pressure and surface roughness is similar to that of the fuel-binder materials. A technical report on this phase of the work will be issued within the next few months.

REPORT OF PROGRESS DURING THE SUBJECT PERIOD (Continued)

The present work was performed using an apparatus designed for vacuum work. A pressure vessel in which the flame spreading velocity can be measured at pressure as high as 350 psi will soon be available. Consequently, soon it will be possible to investigate the pressure dependence of flame spreading velocity over a pressure range that varies by a factor of 100.

PLANS FOR THE COMING PERIOD

During the coming period the following activities are planned:

1) At subatmospheric pressure, continuous enlargement of the range of parameters already tested for various solid propellant materials.

2) At pressure greater than atmospheric, generation of the same type of data already produced at subatmospheric pressure.

3) Measurement of flame spreading rate as a function of initial propellant surface temperature.

4) Investigation of influence of forced convective gas motion parallel to the propellant surface on flame spreading rate.

5) Measurement of heat flux history produced by the spreading flame by using a rapid response surface heat flux gauge.

REFERENCES

1. McAlevy, R. F., III, Magee, R.S. and Wrubel, J. A., "Flame Spreading over the Surface of Double Base propellants," Paper presented at the AIAA Solid Propellant Rocket Conference, Palo Alto, Calif., January 29, 1964.